On the Principles and Fault Maintenance of the Power Amplifier Section in Terrestrial Digital Television Transmitters: Postprint

Authors: Yang Yongcai

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Abstract

The emergence and widespread application of radio signal transmission technology have propelled the development of terrestrial digital television. Such television signals offer broad transmission coverage, diverse program content for viewers, and relatively straightforward deployment compared to other television systems. Consequently, the stable operation of digital television transmitters has become an increasingly critical concern and focus of investigation for technical professionals. This paper first introduces the evolutionary trajectory of transmitters, expounds upon the device composition, structural configuration, and operational principles of transmitters and their power amplifier modules, presents a structural analysis and principle exposition specifically for the transmitter power amplifier section—identified as the component most susceptible to failures within the system—analyzes several common malfunction issues, and proposes targeted repair and maintenance methodologies, with the objective of ensuring the safe and stable operation of equipment and guaranteeing the secure, high-quality broadcast of radio and television programs.

Full Text

Abstract

The emergence and widespread application of radio signal transmission technology has propelled the development of terrestrial digital television. This television signal type features broad transmission coverage, diverse program offerings for viewers, and relatively straightforward deployment compared to other television systems. Consequently, the stable operation of digital television transmitters has become an increasingly critical concern for technicians. This paper first reviews the evolution of transmitters, discusses the component structure and operational principles of transmitters and power amplifier (PA) modules, and provides structural analysis and principle introduction for the transmitter PA section—where faults most frequently occur. The paper analyzes common failure issues and proposes targeted repair and maintenance methods to ensure safe and stable equipment operation and guarantee secure, high-quality broadcast television transmission.

Keywords: Terrestrial digital television; Transmitter power amplifier; Principle; Fault maintenance

1. Evolution of Terrestrial Digital Television Transmitters

Compared with traditional analog television transmitters, terrestrial digital television transmitters operate with greater stability and reliability. In today' s era of rapid scientific and technological development, conventional analog television transmitters are gradually being replaced by terrestrial digital television transmitters, and national research efforts on digital television transmitters have intensified, creating favorable development opportunities. However, China' s vast territory and complex, diverse topography have resulted in relatively backward technology at many terrestrial digital television transmission stations in remote and mountainous areas in recent years. Many stations have implemented automation through remote monitoring technology. These conditions indicate that the overall operational efficiency of current terrestrial digital television transmitters still requires improvement.

2. Component Structure and Operational Principles of Transmitters and PA Modules

The PA module constitutes a critical component of the transmitter section in television equipment. Technicians should carefully analyze the causes of faults in this module and develop effective maintenance measures based on literature review and practical experience to improve operational efficiency and service life. Currently, the most commonly used PA module is the 400W type, whose structure primarily includes a pre-amplification stage, signal distribution unit, dual-terminal power enhancement stage, and signal processing unit. The power enhancement stage represents the core structure of the PA module. A complete PA module additionally incorporates a thermal dissipation structure and protective housing.

During actual operation, the exciter first performs frequency modulation on the code stream and transmits it as an RF signal. A switcher then performs mode conversion, with one signal path transmitted through a distributor to the 400W PA module. The pre-PA unit receives the high-frequency signal, enabling normal operation of the final-stage power amplifier, which then sends the signal to the antenna. The combiner can isolate RF signals, while the PA cooling system accelerates heat conduction and improves dissipation efficiency. Within the PA module, the RF signal power is enhanced and transmitted through the internal signal processing structure to the antenna device, thereby completing signal transmission.

Terrestrial digital television transmitters consist primarily of a modulator, exciter amplifier unit, main control unit, switches and power supplies, passive components, cooling system, automatic switching unit, and final-stage PA unit. The main control unit further includes a main control board, system detection board, and touchscreen. The LCD screen in the main control unit of terrestrial digital television transmitters can display all operational status and transmission power output parameters. The exciter can automatically identify signals and perform switching. Since terrestrial digital television transmitters typically feature two exciters, they can receive and identify two signal paths. The exciter encodes received signals to ensure interference resistance and correct reception. It also modulates and amplifies received signals for high-quality transmission. When temperature is high or standing wave ratio is excessive, the transmitter shuts down and transmits host status to the main control unit. To isolate input power, an isolation transformer is connected at the input terminal of the low-voltage distribution panel.

Fault detection and elimination first require establishing a proper maintenance platform. This platform should primarily include a data transmission device, PA module connection ports, and backup power supplies. An air switch connects the power supply through the connection port to a 380-volt source. A debugging interface is installed on a configured computer and connected via data transmission cable to ensure consistency between operational parameters and computer-displayed data. Although such maintenance platforms are relatively simple, they effectively facilitate operational status analysis and fault elimination.

3. Analysis of Common PA Module Faults

3.1 Power Transistor Loss

When power transistors experience loss, the overall module power becomes abnormal, manifesting as decreased output power while reflected power remains stable. The current intensity of a single PA module decreases with the output power reduction caused by transistor loss, typically dropping to approximately 25A, making such faults detectable through digital signal monitoring platforms.

Although early-stage transistor loss usually involves package damage, prolonged operation of degraded components leads to overall performance decline. Therefore, timely inspection and complete component replacement are necessary. Using dual-gate LDMOS power transistors as an example, after removing the cover plate, a multimeter in resistance mode can measure the LDMOS resistance value. Normal transistor resistance is approximately 3000 ohms; abnormally high resistance indicates transistor degradation. The output section of transistors often exhibits burnt and detached SMD components. When the entire substrate is burnt and copper surfaces are damaged, circuit board replacement becomes necessary to meet high-frequency circuit requirements. When power transistors experience severe degradation that cannot be promptly replaced, overall power can be reduced to minimize damage to other normal components. Maintaining device power above 3dBm can ensure stable coverage area.

3.2 Output Combiner Line Blockage

This fault exhibits similar symptoms to power transistor loss, with decreased output power appearing on digital signal monitoring platforms, but transistor current intensity remains normal. Additionally, decreased output power in the fault area accompanies increased power in other PA modules, often rising to approximately 600W. The current intensity of the PA module remains stable and normal overall.

Damage to the transmitter transmission module often causes such faults; therefore, emphasis should be placed on inspecting the component structure of this module, checking each component individually. Specific inspections can involve physical contact to determine whether components exhibit overheating. High-power transmission in transmitters requires power enhancement through combiner action, with port resistance values requiring maintenance above 50 ohms and isolation above 20dB to achieve power enhancement and separation. After replacement, technicians should use a vector analyzer to adjust PA phase until power returns to normal levels.

3.3 Elevated Balanced Power in PA Module

Balanced power serves as an important reference for evaluating PA module functionality, with its value depending on phase matching degree and output power among various PA modules. Normal balanced power should be maintained at approximately 2W. Commonly used solid-state transmitters, such as the 10kW decimeter-wave model composed of 32 PA modules, follow this standard.

Deterioration at PA module output sections and circuit nodes often causes abnormal current intensity fluctuations in partial circuits, leading to elevated balanced power. Although severe desoldering issues may not occur in early stages, significant safety threats exist. Therefore, connections should be re-soldered after dust removal.

3.4 Microswitch Loss

This device is typically installed on the protective housing exterior of PA modules, making it susceptible to external mechanical interference that causes decreased contact sensitivity and fracture issues. Microswitches primarily control whether the front-end amplifier is abnormal. Damage to this device can easily cause destruction of connected capacitors, resulting in abnormal gate voltage intensity fluctuations that interfere with normal PA module operation.

To address such issues, maintenance personnel should increase inspection frequency and promptly replace damaged switches. Additionally, switch protection devices should be installed on the protective housing to reduce external damage factors and extend service life.

3.5 PA Tube Damage

Evaluation of PA tube working status can be performed through comprehensive analysis of quiescent current intensity and gate-drain voltage. PA tube damage typically affects PC section amplification. The PA module power supply connects internally to the drain through four parallel resistors (0.05 ohms), allowing quiescent current intensity to be deduced through voltage measurement at the resistor section. When bipolar voltage remains within normal range but current intensity is significantly higher than normal, PA tube damage is indicated.

PA tube damage is typically addressed through replacement. To protect surrounding electrical components and current paths, components near the electrodes should first be removed. After ensuring no critical components are nearby, remove fixing screws with a screwdriver. Debris from the disassembly process should be cleaned using professional solder debris tools or a soldering iron. To ensure personal safety, staff must confirm proper grounding before touching PA tubes to eliminate static electricity. Clean the tube socket with alcohol-soaked cotton and apply thermal grease to the surface, taking care that the grease layer is not excessively thick. After completing these steps, place the replacement component in position and press to ensure good electrode contact. Finally, fix with screws and solder the gate and drain. Soldering time must be strictly controlled—too short compromises stability, while too long may damage circuit boards. PA tubes are often used in groups; single replacement may cause power imbalance, so complete group replacement is preferred. If partial replacement is necessary due to limitations, adjust gate voltage intensity after preheating with power applied to maintain identical quiescent current and balanced power among PA tubes.

3.6 Heat Dissipation and Dust Accumulation

The PA module of transmitters generates substantial heat during routine operation due to power conversion. If this heat cannot be dissipated promptly, accumulated thermal energy causing temperature elevation accelerates oxidation reactions in various electrical components, severely affecting normal module operation while shortening component lifespan. Transmitters commonly dissipate heat through forced air cooling. To further improve dissipation efficiency, refrigeration air conditioning can be added to the cooling fan system. Air conditioning is typically installed on both sides of the transmitter equipment room to improve air flow uniformity. To promote timely heat dissipation, ventilation outlets made of iron duct materials can be installed at transmitter air outlets, with cold air generators placed at ventilation duct exits.

However, such cooling methods may introduce airborne dust particles into the module interior. Inadequate cleaning can cause dust accumulation, which combined with environmental humidity may lead to circuit board short circuits. Maintenance personnel should not only perform regular cleaning but also optimize cooling air intake patterns. First, cooling air should be filtered. Maintenance staff must ensure sealing of the transmitter working environment, strictly closing all gaps except cooling air intakes to prevent dust-laden air entry and reduce dust particles at the source.

In addition to temperature and dust issues, maintenance personnel should also control air humidity in equipment rooms. High moisture content in air degrades high-frequency performance of PA modules, causing electrical component loss. Therefore, equipment rooms should be kept dry and clean.

4. Routine Maintenance Measures for Terrestrial Digital Television Transmitters

PA module fault analysis and elimination constitute an important aspect of television equipment maintenance. Summarizing relevant faults provides valuable references for industry personnel. This paper first briefly overviews PA module component structure and working principles, then analyzes commonly encountered issues including power transistor loss, output combiner line blockage, elevated balanced power, microswitch loss, PA tube damage, and heat dissipation/dust accumulation. The paper discusses fault manifestations and causes, and proposes corresponding maintenance methods. In addition to timely maintenance, personnel should use professional equipment to uniformly adjust operating parameters of PA modules, especially sections where components have been replaced, to ensure stable operation.

Currently, terrestrial digital television transmitter quality has significantly improved with more stable operation, yet various fault types persist. This requires relevant staff to understand and familiarize themselves with transmitter working principles, promptly detect and eliminate faults, and perform regular maintenance. Personnel must conscientiously and responsibly inspect and maintain equipment, paying special attention to PA module maintenance, continuously deepening theoretical knowledge, and comprehensively improving professional competence to meet new era requirements.

Maintenance can be categorized by interval into daily, monthly, quarterly, annual, and comprehensive maintenance.

4.1 Daily Maintenance

Daily maintenance first requires checking antenna connection status of terrestrial digital television transmitters. Antenna status should not be altered arbitrarily whether the transmitter is operating or idle. Display screen content during transmitter operation should be recorded for comparison with factory data, with special attention to exciter display information. Significant deviations from manufacturer data require appropriate adjustment. Antenna feed system faults must be eliminated, particularly monitoring feed line operational status during severe weather conditions such as thunderstorms, snowstorms, or sandstorms to check for deformation, loosening, or breakage, maintaining stable operation. During thunderstorm seasons, grounding status of antenna feed system feed lines should be inspected to eliminate poor contact issues. Technicians must regularly check all indicators and promptly clean dust from transmitters. Improving transmitter operational stability requires maintaining a favorable operating environment with appropriate temperature and humidity.

4.2 Monthly Maintenance

Monthly maintenance requires analyzing staff work records and related data to eliminate quality issues. Power protector operational status should be inspected, with red indicator lights signaling immediate replacement. Transmitter power must be checked regularly, and coaxial equipment surface temperature should be frequently checked manually. Inlet air flow should be maintained unobstructed for transmitter power inlets, with inlet filter cleaning performed at least monthly. Fan covers, blades, and radiators should also be cleaned, with fan operational status verified.

4.3 Annual Maintenance

Annual maintenance includes checking whether all transmitter fans exhibit reduced air power, with immediate replacement required for abnormal operation. Since terrestrial digital television transmitter filters operate periodically, filter functionality should be verified and debugged if necessary. Touchscreen connection status should be inspected, with reconnection or cable replacement for poor contact. Transmitter voltage should be checked, with switching power supplies or electrolytic capacitors replaced as needed. AC contactors on distribution panels should be replaced. Touchscreens with poor contact or display issues should be promptly replaced.

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(Author affiliation: Haidong City Ledu District Radio and Television Bureau, Qinghai Province)